CIRCULAR PLASTICS ECONOMY
The plastics economy must become circular

Plastic is the material of our present and future. Plastics shape our lives and make them easier. Plastics are used in almost all areas of medicine. A quarter of a car consists of plastic. Whether electronics, cosmetics or home furnishings – the versatile material is used everywhere. Plastics are light, functional and inexpensive and are therefore indispensable for resource-efficient products. But the all-rounder plastic is facing some harsh criticism.

A change in how we deal with the polymer all-rounder is required

As a result of inappropriate or inefficient recycling systems within the linear plastics economy, too much plastic is burned or released into the environment. Its image as a disposable article and environmental sinner overshadows the view of plastic’s enormous potential for the future. One thing is clear: It is neither possible nor sensible to renounce plastic. A fundamental change in how we deal with the polymer all-rounder is the only way: The plastics economy must become circular!

But what does a plastic need to be like in order for it and the products made from it to become circular and no longer end up in the environment after use? And: If the plastics do ultimately end up in the environment after all, how can they be degraded quickly and without leaving any residues?

As part of the Fraunhofer Cluster of Excellence “Circular Plastics Economy” (CCPE®), five institutes of the Fraunhofer-Gesellschaft are investigating these questions and, together with stakeholders, developing system services for a functioning circular plastics economy.

The basic ideas behind the research cluster: We want to make the plastics value added chain circular, to extract fewer fossil resources, to use products for a long time, and to reduce end-of-life losses. The switchover from a linear to a circular plastics economy only succeeds with a multi-stakeholder approach. To this end, we are researching systemic, technical, and social innovations – over the entire life-cycle of plastic products – in three divisions and six research departments.
FIGURES FROM THE PLASTICS INDUSTRY

The trend monitor for the plastics industry confirms: The demand for plastics is increasing worldwide. No stagnation is in sight for the time being. By international standards, Europe remains one of the most important research and production locations. The status quo shows where there is potential for the further development of the plastics economy.

**Production and sales**

- World plastics production in 2017 amounted to almost 350 million tonnes, almost 65 million tonnes of which were produced in Europe.
- More than 1.5 million people in around 60,000 companies generated sales of approximately 350 billion euros in the European plastics industry.
- Germany, Italy, France, Spain, the United Kingdom, and Poland represent almost 70 percent of European demand.

**The top 4 application sectors for plastics in Europe**

- **Top 1** Packaging industry (approx. 40 percent*)
- **Top 2** Construction industry (approx. 20 percent*)
- **Top 3** Vehicle construction (approx. 10 percent*)
- **Top 4** Electronics industry (approx. 6 percent*)

* by share of total demand

**Recycling**

According to PlasticsEurope, recycling quantities and quotas of plastic waste have increased in Europe in recent years. Nevertheless, plastic waste is still often sent to landfill here and worldwide or not recycled at all due to a lack of suitable logistics systems, but instead accumulates as waste in the environment. And even in Germany, the model country, more than half of the collected and sorted plastic is used to generate energy, i.e. is incinerated. Very few recycled plastics achieve such high qualities that they become “recycled content” in new products. At the same time, plastic offers great potential for circular economic activity – we will show how this can be unlocked.

Source: Plastics – the Facts 2018, An analysis of European plastics production, demand and waste data, PlasticsEurope
Implementation of the "Sustainable Development Goals"

Ensuring "sustainable consumption and production patterns" is one of the 17 goals of the United Nations' Agenda 2030. The goal specifies that, by 2030, waste generation should be substantially reduced through prevention, reduction, recycling, and reuse.

The EU summarizes the demands of the United Nations under the term "Circular Economy" in concrete political strategies. Intelligent product design, long service life, high collection rates and/or optimized spare parts and repair management are milestones along the path towards the goal.

European plastics manufacturers are reacting with a voluntary commitment: In Europe, plastic packaging should be completely reusable or recyclable from 2040 onwards. The recycling and reuse rate should be 60 percent across the board by 2030.

Fraunhofer Cluster of Excellence “Circular Plastics Economy”

On behalf of the Fraunhofer-Gesellschaft, five Fraunhofer Institutes are researching how the sustainable transformation of an entire plastics value added chain can take place under principles of the circular economy using the example of plastic. The economic and social effects of a circular plastics economy in the coming decades will also be analyzed and taken into account.
Research agenda and structure

The research cluster is divided into three divisions.

Two research departments are assigned to each division. Research and development work is networked throughout the life-cycle of plastic products. Customized plastics, optimized systems, and successful business models are the results of innovation processes.

Assignment: Building a virtual institute

Fraunhofer Clusters of Excellence combine the competencies of institutes to investigate relevant topics with scientific excellence. The directorate and staff of the five Fraunhofer Institutes IAP, ICT, IML, LBF, and UMSICHT are building a virtual institute for the circular plastics economy, which has international connections. Join us in this!
DIVISION "MATERIALS"

We want to use plastics from a sustainable mix of resources to develop functional and long-lasting materials and close material cycles. Formulations for polymers and compounds will themselves be based on circular principles. New additive systems will provide for stable recyclates, multiple recycling loops, and – where necessary – controlled degradation in the environment.

Research department "Circular Polymers"

At the beginning of the plastics value added chain, there is the polymer, a chemical substance consisting of macromolecules. Synthetic or semi-synthetic polymers are the main components in the production of plastics. We are researching new polymer syntheses and processing methods to obtain recyclable and degradable materials based on renewable raw materials.

Investigation into aging and degradation behavior

In order to combine bio-based building blocks into new polymers, we are further developing existing synthesis techniques or transforming the chain architecture of known polymers accordingly. We are also working on innovative processing technologies to develop self-reinforced one-component materials.

A particular focus of our research activities lies on the aging and degradation behavior of plastics. The various life-cycle phases and environmental influences are simulated under realistic conditions using test stands. For example, certain parameters such as temperature, UV light, oxygen, and moisture provide important information in order to control the desired degradation behavior in a targeted manner.

Are you interested in further information about the division "Materials"?
Then send us an email to materials@ccpe.fraunhofer.de.
**Research department “Circular Additives and Compounds”**

We want to optimize the functionality and service life of conventional and bio-based polymers. Additives play a crucial role in this. They are added to the products as additives in order to ensure gentle and safe processing and to enable long-term properties. What’s more, the properties of plastics are specifically adjusted to suit the application.

**Customized additive systems as the basis for new polymers**

We develop precisely tailored additives and compositions that enable the polymers to be used for long periods, to be recycled optimally, or to be biodegradable in a targeted manner. To this end, we are investigating what previous damage and impurities can be found in plastic waste that has been generated through private or commercial use, and how new products can nevertheless result from this. These types of plastics are known as "post-consumer recycled plastic".

In addition, we examine whether and to what extent additive systems made from renewable raw materials can be used and develop new bio-based additive systems that allow – where necessary – controlled degradation in the environment. We are working both on polymers based on fossil raw materials and on bio-based polymers that we modify or develop.
Efficient collection and transport technologies go hand in hand with new recycling processes. In this division, digitally mapped processes are created that lead to optimal value added chain. Intelligent collection, sorting and recycling technologies allow polymers and monomers to be recovered and returned to production. Innovative methods for system analysis are intended to help establish efficient logistics and to evaluate the life-cycles of circular products.

Research department “Advanced Recycling”

A successful circular plastics economy requires optimized collection and sorting processes that are upstream of the recycling of recyclable materials. Advanced process technologies are used to recover polymers and monomers, which are initially fed into the cycle and can then be further processed into products.

We want to optimize the upstream process steps in the current recycling of plastics. The aim is to ensure that, when plastic waste is collected and sorted, a larger quantity of suitable material can be returned to production as a raw material (recycled content). We develop raw material and mechanical processes as well as conceptual aspects in order to obtain polymers and monomers from the industry-specific lifecycles of plastics, which can be processed immediately and used for various applications. We are investigating both chemical recycling processes for conventional and bio-based polymers and recovery strategies for mass plastics such as PS (polystyrene), PET (polyethylene terephthalate), and PU (polyurethane).

We develop conceptual measures for optimized collection and sorting. A holistic approach is particularly important: Our comprehensive analysis thus takes into account parameters such as eco-efficiency and the cost-benefit ratio. The result is a catalog of measures that includes the various sectors and types of plastics and takes account of country-specific waste management developments.

Are you interested in further information about the division “Systems”? Then send us an email to systems@ccpe.fraunhofer.de.
Research department “Circular Logistics and Sustainability”

The Research Department is developing innovative processes for efficient logistics, and sustainability assessments are intended to lead to optimised recycling of plastics. In addition, new evaluation methods are to be developed that indicate the direction of material and product innovations and will allow the circular life-cycle of plastics streams to be monitored in the future.

Digital twin for process management and ecological evaluation

A complete digital recording of the respective state of recycling is required in order to carry out and evaluate the recycling of plastics efficiently in the long term.

With the help of virtual images of plastics and products, for which new methods are being developed in the research cluster, digital transparency is created as the basis for life-cycle-wide process data management. The concept of the “digital twin” will make it possible in the future to track plastics in the cycle and evaluate them economically and ecologically. In addition, we are researching social aspects and involving plastics stakeholders from business, science, and society in new measures for circular value creation.
DIVISION "BUSINESS"

Fraunhofer offers new system services for plastics within the circular economy across industry boundaries: from evaluation tools, circular product designs, prototypes, and recycling to acceptance processes and business models. New developments from the divisions “Materials” and “Systems” are demonstrated in prototypes and tested in practice. Marketing strategies suitable for circular products are also developed.

Research department “Application and Demonstration”

Using two demonstrators, we develop industry-related circular product designs. The development is based on the previous circular assessment of existing products. In addition to high economic efficiency and a long service life, the demonstrators should above all be easy to repair and recycle and their materials should be degradable in the environment if required.

Demonstrators for transfer to industry

We combine the newly developed concepts, materials, and systems from the divisions “Materials” and “Systems” into two demonstrators. We have selected demonstrators with great innovation potential that address a specific market and can easily be transferred to other products.

Demonstrator 1  Reusable transport containers for online retail
Demonstrator 2  Child safety seat, representative of other seat systems

Together with the industry, we develop the necessary process technologies and possible applications for the specific product. Alongside new processing technologies, the focus lies on the development of new circular design concepts for recyclable products. The focus is on durability, reparability, and adaptability.

Are you interested in further information about the division “Business”? Then send us an email to business@ccpe.fraunhofer.de.
Research department "Business and Transformation"

The transition to a successful circular plastics economy is successful if innovative marketing strategies and new business models are integrated into the entire value creation network.

Knowledge base as the basis for a successful transformation

We are establishing an extensive database as the basis for a successful recycling strategy:

- Information on different recyclable material streams
- Information on the targeted reuse of recycling streams
- Information on the most ecologically and economically sensible method of recycling

We are planning a Fraunhofer quality label and our own Circular Economy Assessment under the CIRCONOMY® brand as new design instruments for change. This toolbox is used to investigate the degree of circularity of materials and products at an early stage. The results are then employed to determine the direction and path of promising material, system, and product innovations. They form the starting point for a new innovation cycle.
In a word: What the players in the cluster say

1 Darmstadt
Fraunhofer LBF provides solutions for structural durability, system reliability, vibration technology, and plastics.

“Mechanical recycling makes a significant contribution to overcoming the central challenges of our time in a sustainable manner. It has enormous technical and economic potential if it is possible to replace primary plastics with high-quality recycled materials. Customized recycled material additives are the key components for this. This is a central task that the partners in our cluster are tackling.”
Prof. Dr.-Ing. Tobias Melz, Director of Fraunhofer LBF | Division "Materials"/"Business"

2 Dortmund
Fraunhofer IML stands for material flow technology, simulation-based corporate and system planning, traffic systems, and resource logistics.

“By bundling competencies in material and product development, recycling technology, digitalization, business development, and logistics across institutes, we support the recycling of plastics and create systemic added value for the circular plastics economy.”
Prof. Dr.-Ing. Uwe Clausen, Director of Fraunhofer IML | Division "Systems"

3 Oberhausen
Fraunhofer UMSICHT develops efficient processes, environmentally-friendly technologies, and sustainable products.

“We want to reorganize the plastics economy. We want to drive forward a rethink as regards the production, use, disposal, and recycling of plastics. This is a system-relevant task. For this reason, the Fraunhofer Cluster of Excellence ‘Circular Plastics Economy’ relies on a research structure consisting of five partner institutes that transcend institute boundaries.”
Prof. Dr.-Ing. Eckhard Weidner, Director of Fraunhofer UMSICHT | Head of the Cluster
"Organizationally, the research cluster forms a ‘virtual institute’, which is spread over five locations. Fraunhofer research clusters do not only aim at the temporary implementation of a single project, but rather pursue a roadmap for the long-term development of a complex technology trend."
Dr.-Ing. Hartmut Pflaum, Fraunhofer UMSICHT | Central office of the Cluster

"Only with a systemic approach, as is pursued in the cluster, can the future challenges of the plastics processing industry with regard to a ‘circular economy’ approach be mastered. In addition to the efforts to develop new, sustainable raw material and mechanical concepts, a rethinking of product design is also necessary to achieve a closed material cycle for plastic products."
Prof. Dr.-Ing. Peter Elsner, Director of Fraunhofer ICT | Division “Systems”

"Plastics do not have to be produced from the fossil resource oil, nor do they have to pollute the environment. Bio-based and/or biodegradable plastics – currently still a niche – will make their contribution to a circular plastics economy. We are working on this in the division ‘Materials’."
Prof. Dr. rer. nat. Alexander Böker, Director of Fraunhofer IAP | Division “Materials”

4 Pfinztal
Fraunhofer ICT is competent in chemical processes, energetic systems, explosives technology, new drive systems, plastics technology, and composites.

5 Potsdam
Fraunhofer IAP gets polymers ready for the future and covers the entire range of polymer applications.
INTERESTED?

YOUR CONTACT PERSONS

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Further information: www.ccpe.fraunhofer.de